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**RESEARCH
NOTES:**

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Evaluation of Off-Ramp Right Turn Control at Single Point Urban Interchanges Without Frontage Roads

INTRODUCTION

Single point urban interchanges (SPUIs) have become an integral part of managing traffic at the critical connections between freeway and arterial roadway systems. Although studies and debates continue as to where and how they should be applied, they do not discount their continued application. Based on this more widespread use, finer aspects of their operation are being considered and studied. This study focused on the control of the off-ramp right turn movement at SPUIs without frontage roads. The objective of this research project was to evaluate the safety and efficiency of traffic control for off-ramp right turns. For the purposes of this project, two common forms of off-ramp right turn traffic control were investigated: signal control and yield control..

SCOPE OF RESEARCH

The process followed during this research focused on two main aspects of the off-ramp right turn movement: safety and operations. The project was composed of the following stages:

Literature Review: A literature review was conducted to provide the research team a broader perspective on other studies concerned with this aspect of SPUIs. The review was looking for the various traffic controls and interchange configurations that could particularly affect the safety and operation efficiency of off-ramp right turn movement.

Safety Analysis: Long-term trends in crash occurrences and short-term observations of conflicts at six study sites (12 off-ramp locations) were analyzed. Crash rates and conflict rates were determined in order to compare and contrast the two means of assessing safety as well as how they relate to the type of the traffic control used at the off-ramps.

Operations Analysis: Detailed traffic data collected at the study sites was used to calculate actual delays for off-ramp right turn movements at the study sites. This field data was also used to conduct simulations of interchange which supplemented the calculations based on the limited sample of study sites. The simulation models provided a means of testing different combinations of off-ramp right turn control types and overall interchange conditions in order

to determine the effects of signal and yield control.

FINDINGS & CONCLUSIONS

The review of relevant literature and research shows that there is some attention devoted to the operation and safety of SPUIs specifically pertaining to the off-ramp right turn movement. The literature review also revealed that there does not appear to be any past or present research/studies investigating the advantages and disadvantages of using one form of control over another for the off-ramp right turn movement. Most of the information reviewed pertained to the advantages and disadvantages of free/uncontrolled off-ramp right turn movements versus some type of control (i.e., stop sign, yield, or signal). Key concepts relating to the types of off-ramp right turn control that were discovered during the literature review and considered throughout the research included the effect of nearby downstream intersections, pedestrian/bicyclist activity at the interchange, increased clearance intervals with signal control, and other issues further discussed within the report.

The data collection effort and details obtained from observations and research allowed for actual calculations to be made concerning operations and safety. Interpretation of that data through the results of the calculations lends itself to determining interchange characteristics that influence operations and/or safety, but is subject to the limited number (6) of study interchanges evaluated. Qualitative observations and conclusions regarding the operations and safety of the study interchanges are presented within this report.

Delays, conflict rates, and crash rates were calculated from the data and observations at the six study sites. Average delays for off-ramp right turn vehicles at signal-controlled locations experienced about 20% to 30% more delay than the vehicles at locations with yield control. The overall conflict rates for the control-type groups were based on a recalculation of the conflict rate using the summed values for each sample site. An overall average of the crash rates calculated

for each site was not deemed appropriate given the variability inherent to conflict observations based on the relatively short observation period as compared to crash rate calculations. The average conflict rate for the yield-controlled sites as a group is about 240% greater than the average rate for the signal-controlled group, but the yield-controlled sites have considerable variability in their rates. A statistical t-test indicates that because of this variability and despite the large difference in average rates, there is no significant difference ($t_{\text{calc}} = 1.705$, $t_{.05, v=10} = 1.812$) in the average conflict rates between the control groups. Overall crash rates for the control-type groups were the averaged values of the three-year average crash rate for each site in the group. The average crash rate for yield-controlled sites as a group is almost double the average crash rate for the signal-controlled sites. This ratio is comparable to the conflict rate relationship between the two groups. A statistical t-test was performed on the average crash rate data for the yield-controlled sites and the signal-controlled sites. All crash rates were considered, which resulted in no significant difference ($t_{\text{calc}} = 1.510$, $t_{.05, v=10} = 1.812$) in the average rates for each group.

The actual field data from the limited sample of study interchanges was supplemented with model simulation results that considered four control type scenarios—two variations on signal control and two on yield control. The signal control variations concern the allotment of signal phasing to the off-ramp right turn traffic. One version only gives a green arrow indication to the off-ramp right turn movement during the adjacent cross street left turn phase. This was referred to as “Signal 1-phase” within this report. The other variation of the off-ramp right turn signal control type is when there are two phases that can provide the green arrow indication for the off-ramp right turn movement. This control variation is referred to as “Signal 2-phase” in this report.

The yield control type was split into two versions incorporating vehicle presence detection or just the standard yield sign with no vehicle detection. The off-ramp right turn control that uses yield signs and vehicle

detection works similarly to the Signal 1-phase control, but without the signal head indications for the off-ramp right turn vehicles. Essentially the off-ramp right turn traffic would be acting as pseudo cross street left turn traffic. In this report, this control type is called “Yield With Detection.”

An iterative analysis process involving a range of off-ramp and interchange volume conditions was used to determine overall operational effectiveness of each control scenario. Data collected at several SPUI sites was used to calibrate a micro-simulation model (CORSIM) that was then used to evaluate numerous combinations of traffic volume conditions and off-ramp control types that would have not been possible to collect at actual SPUI locations. The results of the simulations were used in concert with the safety evaluation and conclusions to develop suggestions on appropriate control types for the off-ramp right turn movement.

The results indicated that in almost all volume scenarios, the “Yield Without Detection” control type (the basis for the comparisons) has the lowest overall interchange control delay. When comparing averaged interchange control delays, the other control type variations resulted in more delay. In the scenarios with one off-ramp right turn lane, the overall interchange delay for the “Yield With Detection” and “Signal 1-Phase” were not much greater (about 4 and 9 % more, respectively). The differences in interchange delay were more prominent in the two-lane off-ramp right turn scenarios due to modeling constraints, which caused the left hand lane of the two lane off-ramp right turn to experience more delay than necessary in the scenarios with signal control. Therefore, the magnitudes of the percent differences for the signal control types in this two-lane group of scenarios are exaggerated, yet they still reflect the same general relationship as the one-lane group of scenarios. Also, note that these percent differences apply for the normal ranges of interchange volumes and turning movements used in this project. Unusual situations may result in different results for each control type.

The efforts executed during this project had the goal of determining which control type would be best to use for off-ramp right turn movements at single-point urban interchanges without frontage roads. The data collected, both in the field and through the crash databases, were very detailed, beneficial, and used to their fullest. However, despite the efforts and underlying goal, the results from the safety and operations analyses appear to be contrary making it necessary to compare the two aspects using a common basis. Safety and operation can be measured in the common term of cost. Estimates of the overall yearly costs of operations and crashes associated with the off-ramp right turn movement at yield and signal-controlled site were computed as a final means of determining the best control type.

The crash cost for each interchange is calculated from the number of crashes associated with the off-ramp right turn movement only. Thus, the total crash cost values are not representative of the total crash costs per interchange, but are valid for use in the comparison against interchange operational costs since the unknown crash cost component is assumed to be equal for all the interchanges. The costs are composed of several factors: medical costs, property damage loss, lost productivity (market and household), and other related costs. The average costs for crashes involving property damage only was \$4,812 (in 2004 dollars). Crashes involving injuries of varying degrees have an average cost of \$49,817. Crashes with any fatalities, which are about 75 times less likely to occur as other injury crashes, have an average cost of \$1,184,885 associated with them. The average yearly cost of crashes for the study interchanges, grouped by off-ramp right turn control type, indicates that interchanges using yield control for the off-ramp right turn movement are about \$384,000 (2004 dollars) more costly than the interchanges using signal control.

The user cost aspect considered in this project was the “value of time” (user delay costs), which accounts for a majority of the user costs in this project’s comparison of the control types for off-ramp right turn movements. The value of time is a function of the average hourly wage earned by the persons impacted by the delays (separated

by passenger vehicles and trucks), the percentage of the hourly wage considered as the value of time (50% for passenger vehicles, 100% for trucks), and the average passenger occupancy (1.5 for passenger vehicles, 1.05 for trucks). The average yearly cost of delay for the study interchanges, grouped by off-ramp right turn control type, indicates that interchanges using signal control for the off-ramp right turn movement are about \$689,000 more costly.

For use in this comparison only, the total average yearly costs (crash costs + delay costs) for interchanges using signal control for the off-ramp right turn movement is estimated at \$2,100,000. Interchanges that have yield control for the off-ramp right turn movement have an average yearly cost estimate of \$1,800,000. Despite yield control sites appearing to have higher crash rates (although not statistically significant), their overall savings in user cost of delay offsets the increased costs of crashes.

However, the difference in total costs does not appear to be substantial, at least not to a degree where the selection of a certain control type would be more convincing than the other.

IMPLEMENTATION

This research project and its associated analysis have determined that neither signal nor yield control has an overwhelming advantage over the other with respect to the combined safety, operations, and costs associated with off-ramp right turn movements at SPUIs without frontage roads. Therefore, suggested implementation of one control over the other is unwarranted. A more extensive research study with an expanded sample of interchanges may yield more detailed conclusions which might suggest changes to current traffic control protocols.

The full report: *Evaluation of Off-Ramp Right Turn Control at Single Point Urban Interchanges Without Frontage Roads* by Jim C. Lee, P.E., Ph.D.; James A. Bonneson, P.E., Ph.D.; Brennan D. Kidd, P.E.; and Karl H. Zimmerman, of Lee Engineering & Texas Transportation Institute (Arizona Department of Transportation, report number FHWA-AZ-05-556, published January 2006) is available on the Internet. Educational and governmental agencies may order print copies from the Arizona Transportation Research Center, 206 S. 17 Ave., MD 075R, Phoenix, AZ 85007; FAX 602-712-3400. Businesses may order copies through ADOT's Engineering Records Section.